IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

HONEYWELL INTERNATIONAL INC. and HONEYWELL INTELLECTUAL PROPERTIES INC., Plaintiffs, v. APPLE COMPUTER, INC., et al., Defendants.	)	C.A. No. 04-1338 (KAJ)
HONEYWELL INTERNATIONAL INC. and HONEYWELL INTELLECTUAL PROPERTIES INC., Plaintiffs, v. AUDIOVOX COMMUNICATIONS CORP., et al., Defendants.	)	C.A. No. 04-1337 (KAJ)
OPTREX AMERICA, INC., Plaintiff, v. HONEYWELL INTERNATIONAL INC. and HONEYWELL INTELLECTUAL PROPERTIES INC., Defendants.	)	C.A. No. 04-1536 (KAJ)

NOTICE OF SUBPOENA
DIRECTED TO RICHARD I. MCCARTNEY

PLEASE TAKE NOTICE that pursuant to Rule 45 of the Federal Rules of Civil Procedure, Optrex America, Inc. ("Optrex") has served a subpoena duces tecum upon Richard I. McCartney, in the form appended hereto, for the production on September 13, 2006 of the documents described in "Attachment A" to the subpoena.

August 15, 2006

YOUNG CONAWAY STARGATT & TAYLOR, LLP

Karen L. Pascale

Karen L. Pascale (#2903) [kpascale@ycst.com]
The Brandywine Building
1000 West Street, 17th Floor
Wilmington, DE 19801
(302) 571-6600

- and -

Richard D. Kelly
Andrew M. Ollis
Alexander E. Gasser
OBLON, SPIVAK, MCCLELLAND,
MAIER & NEUSTADT, P.C.
1940 Duke Street
Alexandria, VA 22314
(703) 413-3000
Attorneys for Optrex America, Inc.

• AO88 (Rev. 1/94) Subpoena in a Civil Case

UNITED STATES DISTRICT COURT

FOR THE NORTHERN DISTRICT OF CALIFORNIA

OPTREX AMERICA, INC.

v.

HONEYWELL INTERNATIONAL INC., et al.

SUBPOENA IN A CIVIL CASE

PENDING IN THE U.S. DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

CASE NO. 04-1536 (KAJ)

TO: Richard I. McCartney
210 Oak Creek Blvd.
Scotts Valley, CA 95066

c/o Matthew Woods, Esq.
Robbins, Kaplan, Miller & Ciresi L.L.P.
2800 LaSalle Plaza
800 LaSalle Avenue
Minneapolis, MN 55402

☐ YOU ARE COMMANDED to appear in the United States District court at the place, date, and time specified below to testify in the above case.

PLACE OF TESTIMONY	COURTROOM DATE AND TIME

☐ YOU ARE COMMANDED to appear at the place, date, and time specified below to testify at the taking of a deposition in the above case.

PLACE OF DEPOSITION	DATE AND TIME

☑ **YOU ARE COMMANDED to produce and permit inspection and copying of the following documents or objects at the place, date, and time specified below (list documents or objects):**

See Attachment A

PLACE	DATE AND TIME
OBLON, SPIVAK, MCCLELLAND, MAIER & NEUSTADT, P.C. 1940 Duke Street Alexandria, VA 22314	September 13, 2006, 9:00 am

☐ YOU ARE COMMANDED to permit inspection of the following premises at the date and time specified below.

PREMISES	DATE AND TIME

Any organization not a party to this suit that is subpoenaed for the taking of a deposition shall designate one or more officers, directors, or managing agents, or other persons who consent to testify on its behalf, and may set forth, for each person designated, the matters on which the person will testify. Federal Rules of Civil Procedure, 30(b)(6).

ISSUING OFFICER'S SIGNATURE AND TITLE (INDICATE IF ATTORNEY FOR PLAINTIFF OR DEFENDANT)		DATE
Alexander E. Gasser	Attorney for Plaintiff Optrex America, Inc.	August 14, 2006

ISSUING OFFICER'S NAME, ADDRESS AND PHONE NUMBER:

Alexander E. Gasser, Esq.
OBLON, SPIVAK, MCCLELLAND, MAIER & NEUSTADT, P.C.
1940 Duke Street
Alexandria, VA 22314
(703) 413-3000

(See Rule 45, Federal Rules of Civil Procedure, Parts C & D on next page)

PROOF OF SERVICE

	DATE	PLACE
SERVED		

SERVED ON (PRINT NAME)	MANNER OF SERVICE

SERVED BY (PRINT NAME)	TITLE

DECLARATION OF SERVER

I declare under penalty of perjury under the laws of the United States of America that the foregoing information contained in the Proof of Service is true and correct.

Executed on ____________________ ____________________

DATE SIGNATURE OF SERVER

____

ADDRESS OF SERVER

____

Rule 45, Federal Rules of Civil Procedure, Parts C & D:

(c) PROTECTION OF PERSONS SUBJECT TO SUBPOENAS.

(1) A party or an attorney responsible for the issuance and service of a subpoena shall take reasonable steps to avoid imposing undue burden or expense on a person subject to that subpoena. The court on behalf of which the subpoena was issued shall enforce this duty and impose upon the party or attorney in breach of this duty an appropriate sanction which may include, but is not limited to, lost earnings and reasonable attorney's fee.

(2) (A) A person commanded to produce and permit inspection and copying of designated books, papers, documents or tangible things, or inspection of premises need not appear in person at the place of production or inspection unless commanded to appear for deposition, hearing or trial.

(B) Subject to paragraph (d) (2) of this rule, a person commanded to produce and permit inspection and copying may, within 14 days after service of subpoena or before the time specified for compliance if such time is less than 14 days after service, serve upon the party or attorney designated in the subpoena written objection to inspection or copying of any or all of the designated materials or of the premises. If objection is made, the party serving the subpoena shall not be entitled to inspect and copy materials or inspect the premises except pursuant to an order of the court by which the subpoena was issued. If objection has been made, the party serving the subpoena may, upon notice to the person commanded to produce, move at any time for an order to compel the production. Such an order to comply production shall protect any person who is not a party or an officer of a party from significant expense resulting from the inspection and copying commanded.

(3) (A) On timely motion, the court by which a subpoena was issued shall quash or modify the subpoena if it

(i) fails to allow reasonable time for compliance,
(ii) requires a person who is not a party or an officer of a party to travel to a place more than 100 miles from the place where that person resides, is employed or regularly transacts business in person, except that, subject to the provisions of clause (c) (3) (B) (iii) of this rule, such a person may in order to attend trial be commanded to travel from any such place within the state in which the trial is held, or
(iii) requires disclosure of privileged or other protected matter and no exception or waiver applies, or
(iv) subjects a person to undue burden.

(B) If a subpoena

(i) requires disclosure of a trade secret or other confidential research, development, or commercial information, or
(ii) requires disclosure of an unretained expert's opinion or information not describing specific events or occurrences in dispute and resulting from the expert's study made not at the request of any party, or
(iii) requires a person who is not a party or an officer of a party to incur substantial expense to travel more than 100 miles to attend trial, the court may, to protect a person subject to or affected by the subpoena, quash or modify the subpoena, or, if the party in who behalf the subpoena is issued shows a substantial need for the testimony or material that cannot be otherwise met without undue hardship and assures that the person to whom the subpoena is addressed will be reasonably compensated, the court may order appearance or production only upon specified conditions.

(d) DUTIES IN RESPONDING TO SUBPOENA.

(1) A person responding to a subpoena to produce documents shall produce them as they are kept in the usual course of business or shall organize and label them to correspond with the categories in the demand.

(2) When information subject to a subpoena is withheld on a claim that it is privileged or subject to protection as trial preparation materials, the claim shall be made expressly and shall be supported by a description of the nature of the documents, communications, or things not produced that is sufficient to enable the demanding party to contest the claim.

ATTACHMENT A

DEFINITIONS

1. As used herein, the term "document" shall refer to, without limitation, printed, typed, recorded, photocopied, photographed, graphically or electronically generated, or stored matter, however produced or reproduced, including originals, copies, and drafts thereof, which may be considered a "document" or "tangible thing" within the meaning of Rule 34 of the Federal Rules of Civil Procedure, including but not limited to all patents and all applications, foreign or domestic, as well as correspondence and filings in connection therewith, contracts, agreements, guarantees, amendments, assignments, offers, prospectuses, proxy statements, invoices, purchase orders, research and development records, production records, quality control records, management reports, audit reports, accounting reports, work papers, ledgers, balance sheets, profit and loss statements, financial statements, memoranda, correspondence, communications, computer printouts, computer tapes or disks, envelopes, summaries, analyses, opinions, projections, forecasts, budgets, estimates, transcripts, tape recordings, business cards, notes, calendar or diary entries, newspaper articles advertisements, pamphlets, periodicals, pleadings, indexes, file folders and press releases.

2. As used herein, the terms "Plaintiffs," and/or "Honeywell" shall refer to Honeywell International, Inc. and Honeywell Intellectual Properties Inc., and all divisions, departments, subsidiaries (whether direct or indirect), parents, affiliates, acquisitions, predecessors and entities controlled by any of them, whether domestic or foreign, including but not limited to, Allied Corporation, Bendix Corp., Honeywell Inc., Allied-Signal, and/or AlliedSignal and their respective present or former officers, directors, employees, owners, attorneys and agents, as well as consultants and any other persons acting or purporting to act on behalf of each such entity or person.

3. As used herein, the term "you" or "your" shall refer to Richard I. McCartney, Jr. individually and/or Richard I. McCartney, Jr. acting on behalf of Honeywell.

4. As used herein, the term "communication" shall refer to any and all exchanges of information between two or more persons by any medium, including, but not limited to, meetings, telephone conversations, correspondence, memoranda, contracts, agreements, e-mails, computer, radio, telegraph, or verbal actions intended to convey or actually conveying information or data.

5. As used herein, the term "relate" or "relating" shall mean embodying, concerning, containing, comprising, constituting, indicating, referring to, identifying, describing, discussing, involving, supporting, reflecting, evidencing, or otherwise in any way pertaining directly or indirectly to.

INSTRUCTIONS

1. As used herein, the use of the singular form of any word shall include the plural and vice versa.

2. As used herein, the connectives "and" and "or" shall be construed either disjunctively or conjunctively so as to acquire the broadest possible meaning.

3. As used herein, the terms "any," "all" or "each" shall be construed as "any, all and each" inclusively.

4. These requests shall apply to all documents in your possession, custody, or control at the present time or coming into your possession, custody, or control prior to the date of the production. If you know of the existence, past or present, of any documents or things requested below, but is unable to produce such documents or things because they are not presently in your possession, custody, or control, you shall so state and shall identify such documents or things, and the person who has possession, custody, or control of the documents or things.

5. For each and every document for which you assert either attorney-client privilege, work product protection, or some other allegedly applicable privilege, (1) identify the document by date, title, nature, author, sender, recipients, and/or participants; (2) provide a summary statement of the subject matter of the document sufficient in detail to permit a determination of the propriety of your assertion or such privilege or protection; and (3) identify the allegedly applicable privilege or protection.

6. These document requests seek answers current to the date of response, and further shall be deemed to be continuing under Rule 26 (e) of the Federal Rules of Civil Procedure, so that any additional documents referring or relating in any way to these document requests which you acquire or which becomes known to you up to and including the time of trial shall be produced promptly after being so acquired or known by you.

DOCUMENTS AND THINGS TO BE PRODUCED

1. All documents relating or referring to the preparation and prosecution of patent applications that resulted in U.S. Patent No. 5,280,371, listing you, Mr. Daniel D. Syroid and Ms. Karen E. Jachimowicz as inventors, and all related U.S. and foreign patent applications, including invention disclosure documents, prosecution histories, draft applications, prior art, scientific articles or publications, and translations of any such documents.

2. All inventor notebooks or other documents relating to the conception, reduction to practice, research, development, testing, implementation, or analysis of the subject matter described in U.S. Patent No. 5,280,371.

3. All documents relating or referring to any work performed by you, Mr. Daniel D. Syroid or Ms. Karen E. Jachimowicz, or any other person, involving moiré patterns caused by the interaction of cathode ray tubes (CRTs) or liquid crystal displays (LCDs) with other optical elements as seen by the viewer of the image on the CRTs and/or LCDs prior to January 18, 1994.

4. All documents relating or referring to any work performed by you, Mr. Daniel D. Syroid or Ms. Karen E. Jachimowicz, or any other person, involving moiré patterns in active-matrix liquid-crystal light valve (AMLCLV) projection displays and active-matrix liquid-crystal direct-view displays prior to January 18, 1994.

5. All documents relating or referring to the use of multiple lens arrays or other optical elements having different pitches to affect moiré patterns between such optical elements in systems or devices containing cathode ray tubes (CRTs) or liquid crystal displays (LCDs) prior to January 18, 1994.

6. All documents relating or referring to the rotation of one or more lens arrays or other optical elements to affect moiré patterns prior to January 18, 1994.

7. All documents relating or referring to any work performed by you, Mr. Daniel D. Syroid or Ms. Karen E. Jachimowicz, or any other person, involving projection systems using both horizontal and vertical lenticular lens screens prior to January 18, 1994.

8. All documents relating or referring to the need for a Lambertian diffuser as described in U.S. Patent No. 5,280,371.

9. All drafts and versions of the article entitled *Directional Diffuser Lens Array for Backlit LCDs* written by you and Mr. Daniel D. Syroid that was published in "Japan Display (1992)", pages 259-262 (attached hereto as Exhibit A), including all prior drafts exchanged with the publisher prior to publication.

10. All documents relating or referring to any work performed by you, Mr. Daniel D. Syroid or Ms. Karen E. Jachimowicz, or any other person, for the Traffic-Alert & Collision Avoidance System (TCAS) program (including, but not limited to TCAS II) prior to January 18, 1994.

11. All documents that refer or relate to any work performed by you, Mr. Daniel D. Syroid or Ms. Karen E. Jachimowicz, or any other person, with Japan Aviation Electronics Ltd. to the extent such work relates to products that include or consist of LCD modules or components thereof, prior to January 18, 1994.

12. All documents that refer or relate to any work performed by you, Mr. Daniel D. Syroid or Ms. Karen E. Jachimowicz, or any other person, with Hosiden Corp. to the extent such work relates to products that include or consist of LCD modules or components thereof, prior to January 18, 1994.

13. All documents that refer or relate to any work performed by you, Mr. Daniel D. Syroid or Ms. Karen E. Jachimowicz, or any other person, on cockpit displays for aircraft, including, but not limited to the F-16, F-22, C-130, or Boeing 777 aircraft, that include or consist of LCD modules or components thereof, prior to January 18, 1994.

14. All documents relating or referring to communications concerning U.S. Patent No. 5,280,371 and/or the application thereof (Serial No. 911, 547).

15. All documents relating or referring to communications or contact with Honeywell regarding C.A. No. 04-1337-KAJ, C.A. No. 04-1338-KAJ, C.A. No. 04-1536-KAJ or C.A. No. 05-874-KAJ, cases pending in the District of Delaware.

16. To the extent the documents or materials in categories 1-15 no longer exist, all documents that evidence the pertinent document retention policies and destruction of these documents.

Exhibit A

S7-7 Directional Diffuser Lens Array for Backlit LCDs

R. I. McCartney, D. Syroid
Honeywell Inc., Phoenix, AZ, USA

ABSTRACT

A directional type diffuser for backlit liquid crystal displays (LCDs) is presented. Constructed with low-cost, thin, molded plastic lens array(s) and inserted behind the LCD panel, results are: increased brightness, better uniformity, darker blacks off-axis, and better gray-scale stability with viewing angle. The approach is suitable for all transmissive displays including TN, STN, F-E, TVs, laptop PCs, avionics, and other applications.

Objectives and Background

The conventional practice for backlighting large area, liquid crystal, matrix displays (passive or active) consists of a fluorescent lamp behind a diffusing plate that projects light through the LCD.[1] The diffusing plate is typically as lambertian as practical to prevent imaging of the lamp. That is, the diffuser deliberately scatters light uniformly across angle without preference for any direction. This typical configuration serves several practical purposes. Among those practical purposes are hiding the lamp image from the viewer, facilitating the human visual system in establishing the LCD surface as the image plane, and allowing the LCD to be equally well backlit from all viewing angles for a minimum of cost, complexity and space. See Figure 1.

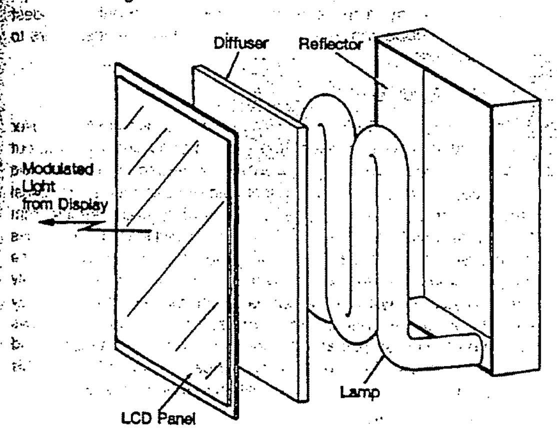

Figure 1. Exploded View of a Typical Backlit LCD

While backlighting through a lambertian diffuser provides virtually constant luminance into the rear display surface throughout all viewing angles, the transmission function of the LCD is not constant with viewing angle. This is a well known shortcoming of LCD technology. Partly due to this transmission instability with viewing angle, the practical uses for this class of display have been limited to applications with confined viewing space such as personal TVs, PC displays, video camera viewfinders, etc. Our application, flight instruments for aircraft cockpits, share common features with typical matrix LCD applications including a limited field of angular view and an undesirable, but significant, instability in the LCD transmission with viewing angle. See Figure 8.

In typical direct view applications, the limited viewing angle actually provides an opportunity to produce a more efficient backlight system. The opportunity arises from the fact that light radiated in unviewed directions is wasted and would be better directed away from those angles into useful viewing angles.[2] Obviously, this is easier said than done. We have developed a means to approach this goal by using a nonlambertian diffuser that has gain in the useful viewing angles. Naturally, as required by the conservation of energy, any gain provided by the diffuser in one direction must be offset by a loss in another direction. This is ideal for the LCD applications described here because it conserves light, directing it preferentially into useful directions while stealing it away from useless angles, thereby improving the efficiency of the backlighting system.

Not only can a directional diffuser improve efficiency, but with proper design choices, it can effectively compensate for the variability of transmission of the display with viewing angle. The directional diffuser, by definition, varies the exit luminance from its surface with viewing angle. By designing this angular variation in luminance output to be inversely proportional to the angular transmission characteristics of the panel, the panel's angular variability can be nullified. That is, when at some angle, the display is more transmissive than it is at the nominal viewing angle, that transmission error can be nullified if the luminous output from the directional diffuser at that same angle is proportionally less than it is at the nominal viewing angle. Conversely, at viewing angles where the panel is less transmissive than it is at the nominal viewing angle, that error can be nullified by a directional diffuser that produces proportionally more luminance at that angle than it does at the nominal angle.

Unfortunately, the angular transmission characteristics of an LCD panel depend largely on the gray level being displayed. It is, therefore, not generally possible to create an inverse transmission characteristic for an LCD panel with a passive directional diffuser. We can, however, approximate that end by targeting particular gray levels or families of gray levels that behave similarly with viewing angle and have a particular importance for the display.

One important gray level to target is the dark state transmission. We believe the dark state variability with viewing angle is closely related to the perceived visual quality of the display's viewing angle. This is especially true in avionics where most of the display surface is black and graphic symbols are displayed against this black background. Often, contrast is presumed to be the important figure of merit with regard to off-axis display performance. We believe, however, that high contrast in off-axis viewing angles is important to a large extent because it is typically used to reduce the dark state, off-axis luminance. That is, a key perceptual factor in accessing display quality across viewing angle is the darkness of the background. That this aspect of display quality is independent of contrast is made clear with the directional diffuser which is incapable of affecting contrast at any viewing angle, but exhibits markedly improved off-axis display quality, nonetheless, in proportions normally attributed to high contrast.

In many applications, including ours, the angular variability of lower gray level transmissions behave similarly to the dark-state transmission. Thus, tailoring the directional diffuser to reduce dark state variability has the added benefit of reducing the variability of lower gray levels as well. Maintaining the luminance stability of these lower gray levels with viewing angle is important to image quality because it is these low gray levels that are recruited to make colors such as brown, gold, and gray, for example. These "colors" are dim versions of orange, yellow and white respectively and depend just as heavily on their relative luminance to the surround

for their perception as they do on their color coordinates. Therefore, to effectively render these colors on the display over the entire angular field of view, it is important that the luminance of the low gray levels be stable with viewing angle.

Results

To construct our original directional diffuser prototype we used an off-the-shelf, 142 lenses per inch (5.6 lenses per mm), molded plastic, cylindrical lens array placed between the LCD panel and a lambertian diffuser. Figure 2 shows our modified diffusing system in cross section. An examination of first principles led us to question how this construction could produce the gains it did since refraction of the light through the lens array from a lambertian source should not produce gain. The subsequent investigation showed that there is a concert of several optical effects combining to produce gain, including diffuse reflections, lens refraction, and total internal reflections.[5] Figure 3 shows the luminance versus angle response from the single cylindrical lens directional diffuser case compared to the angular response from the lambertian source diffuser.

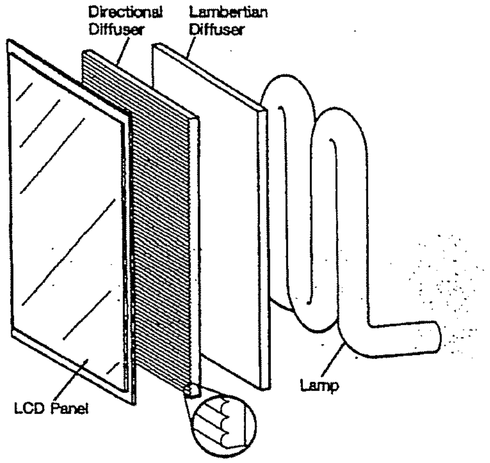

Figure 2. LCD with Directional Diffuser

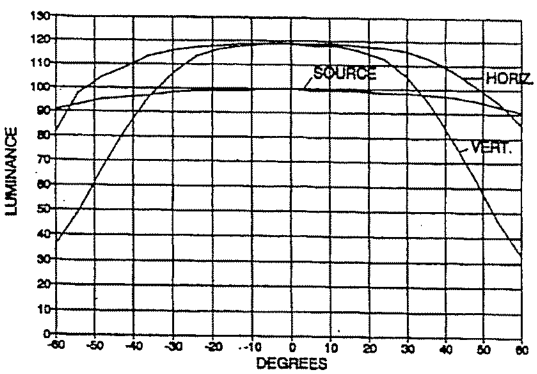

Figure 3. Single Cylindrical Lens Array Angular Emissions

Theory of Operation

As illustrated in Figure 4, light rays from the lambertian diffuser source impinge on the lens array from all angles. Rays with propagation vectors that are substantially perpendicular to the tangent of the lens curvature pass through the lens array sufferin Fresnel reflections at the entrance and exit surfaces of the len array as well as some refraction. Note that these rays are nc necessarily normal to the plane of the array but rather essentiall normal to the curvature of the lens which spans 180 degrees However, much of the intensity of rays substantially off the norma to the array will be reflected back toward the lambertian diffuse source through Fresnel reflections at the entrance surface of th array and at the lens curvature surface. These Fresnel reflection are not, in themselves, losses since the reflected light is directe back toward the lambertian diffuser. There, it is diffusely reflecte again, and together with currently generated light from the lam source, impinges on the lens a second time. However, reflections a the lambertian diffuser source are, in general, lossy as a result o some absorption in the reflections and absorption along the adde optical path. We have found that these losses can be minimized b design choices, especially material selections, at great benefit t the efficiency of the lighting system.

Rays entering at oblique angles relative to the curvature of th lens, that are greater than the critical angle, undergo total interna reflection. These rays are reflected several times around the len periphery and exit the rear of the lens array aimed back at th lambertian diffuser. As described before, these reflected rays the undergo a diffuse reflection from the lambertian diffuser source, an combined with light generated by the lamp source and an presented a second time to the rear of the lens array with anothe chance to pass through the LCD. Since light entering at thes oblique angles is selectively rejected and realigned until accepte by the lens array, the lambertian diffuser and lens array combinatio preferentially transmits light in directions substantially normal to th plane of the array in the axis of the lenslets with only a modes effect on the opposing axis. See Figure 3 where vertical refers t the lenslet axis.

Alternate Configurations

This theory of operation of the prototype directional diffuse configuration serves to illustrate the basic principles involved, bu does not necessarily imply the optimal arrangement or even th preferred construction of an optical element used as a directiona diffuser. For example, another useful configuration results from flipping the lens array over such that the curved lens surface faces the diffuser. In this case, light exiting the diffuser impinges on the convex curvature of the lens array first. This results in preferentially directing light away from the normal to the plane of the lens array and into oblique angles. In other words, this configuration throws light into off-axis angles at the expense of on-axis luminance and can aid in cases where display brightness suffers off-axis. This configuration has an on-axis gain slightly less than one.

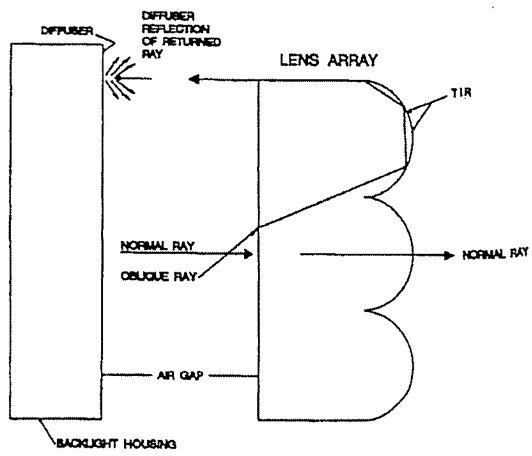

Figure 4. Sample Ray Paths Through Directional Diffuser

Combining multiple lens arrays, stacked one in front of the other relative to the light path, either with the lens' major axis aligned or rotated with respect to each other also has useful effects. Figure 5 illustrates a dual lens array configuration. As you can intuitively imagine, the pitch of the lens array is independent of the transmission versus viewing angle gain profile which depends only on the lens shape. This allowed us to combine the effects of two lens arrays with their major axis aligned without moire pattern effects by using different pitches on each array. This particular arrangement provides sharper roll off of the luminance with vertical viewing angles without much change to the on-axis gain. See Figure 6.

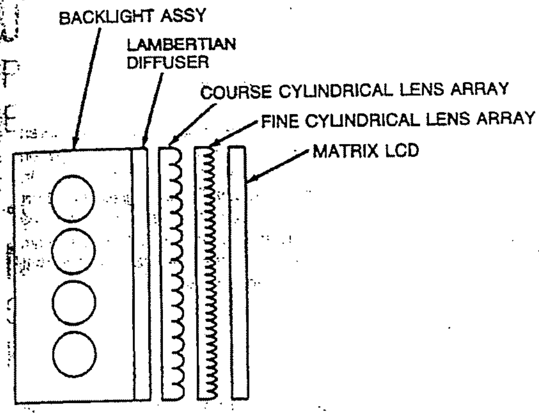

Figure 5. Dual Lens Array Configuration

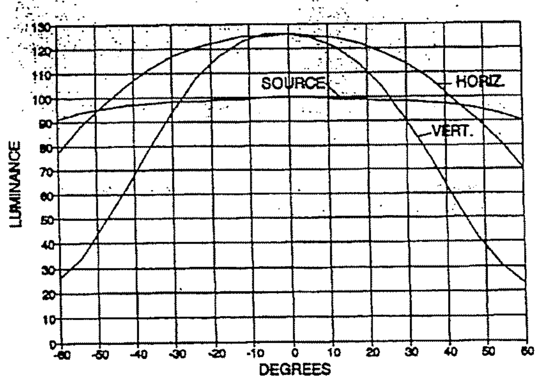

Figure 6. Dual Lens Arrays Optical Characteristic

We have been especially interested in the advantages of such tandem, rotated (90 degrees), lens arrays combined with a diffusing reflector box rather than a diffuser plate as the diffuse source. The advantages are fewer losses and better uniformity due to the larger reflector enclosure serving as an integrating cavity. While the gain profile of the lens array is independent of pitch, the diffusing power of the lenses in this configuration is very much dependent on the lens pitch.

Computer Analysis

Most commercially available optical ray trace programs are designed for imaging optics with lenses placed along an optical axis. These programs are not well suited to analyzing the directional diffuser primarily because of the lateral extension of the diffusing source. Much of our understanding, analysis, and synthesis results of the directional diffuser came about through a customized, ray trace computer program developed for us by Fresnel Technology Inc.[3] Ray tracing of multiple rays with a computer has verified the gains and angular distribution of emitted light from directional diffuser configurations.

This ray trace program was used to examine a number of candidate lens arrays with varying lens shapes. It was found that a triangular array with a 90 degree apex angle provided the most gain on-axis. While the angular distribution was too narrow for our application (see Figure 7), it may be well suited for other applications. The next higher gain was found to be obtained with the cylindrical lens. Asymmetrically shaped or truncated lenses yielded symmetrical angular distributions about the normal axis, but had reduced gain over non-truncated shapes. We also found that while an air gap (or other form of a refractive index discontinuity) must be present between the lambertian diffuser and lens array, the surfaces may contact randomly with no noticeable effect.

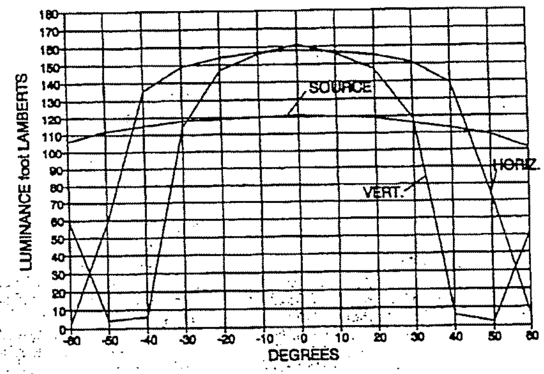

Figure 7. Triangular Lens Array Optical Characteristic

Moire Pattern Treatment

From the beginning we were certain that moire patterns would be a major obstacle to a successful realization of a practical directional diffuser married with an LCD panel. However, we were pleased to find that moire pattern, caused by the beating between the lens pitch and the display dot pitch was much easier to deal with than we first imagined. By using a lens pitch that was higher than, and between integer multiples of, the display pitch we were able to counteract most of the moire.[4] A slight rotation of the lens array's major axis relative to the cardinal axes of the display panel served to frustrate the pattern and thereby eliminate any remaining moire for all practical purposes. Naturally, alphanumeric displays and displays with small, disassociated symbols are least susceptible to moire effects; but we were able to eliminate noticeable moire from all symbols including full-field presentations of solids and patterns.

Combined LCD and Directional Diffuser Results

Figure 8 shows the gray level luminance versus vertical viewing angle for our normally black LCD with a conventional, lambertian diffuser, Figure 9 shows this same panel performance when backlit with the dual-aligned lens arrays profiled in Figure 5. Notice how stable (flat) low level grays are near the nominal viewing angle of 15 degrees up. Also, notice that the black level (lowest gray) remains much darker across viewing angle than when backlit with a conventional diffuser.

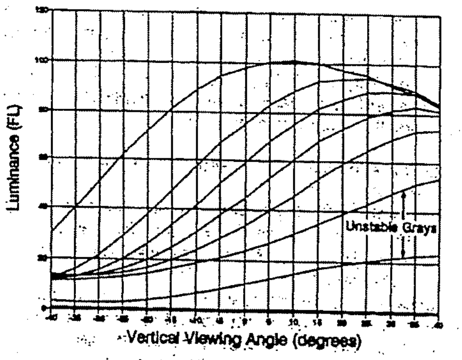

Figure 8. Gray Scale Luminance with Viewing Angle and Conventional Diffuser

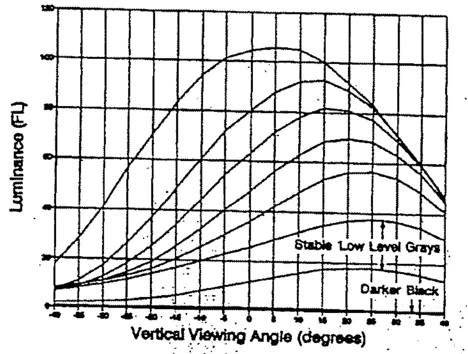

Figure 9. Gray Scale LCD Luminance with Dual Lens Directional Diffuser

Impact

We believe the molded lens array, directional diffuser we have developed and presented here with its approximate 15 percent efficiency improvement to the on-axis output from the backlight system can benefit most LCD applications. The technique is applicable to a wide body of transmissive display technologies including TN, STN, and ferro-electric LCDs. Of particular importance to many applications is that the directional diffuser increases on-axis luminance of the backlight system that can be used in any number of ways including lower lamp power, longer lamp life and/or a brighter display. In portable applications, these benefits can translate directly into longer battery life and/or smaller size and/or lower weight. We believe that for most consumer applications, the efficiency benefit of the directional diffuser alone can justify the relatively low cost of this simple optical element. The benefits of improving display stability with viewing angle and potentially improved display uniformity across the panel, for the most part, come for free.

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CERTIFICATE OF SERVICE

I, Karen L. Pascale, hereby certify that on August 15, 2006, I caused to be electronically filed a true and correct copy of the foregoing document – ***Notice of Subpoena Directed to Richard I. McCartney*** – with the Clerk of Court using CM/ECF which will send notification of such filing to the following counsel of record:

John R. Alison	john.alison@finnegan.com,
Parker H. Bagley	pbagley@milbank.com
Robert J. Benson	rjbenson@hhlaw.com
Robert Karl Beste, III	rkb@skfdelaware.com, vkm@skfdelaware.com
Elizabeth L. Brann	elizabethbrann@paulhastings.com
Christopher E. Chalsen	cchalsen@milbank.com
Hua Chen	huachen@paulhastings.com
Jay C. Chiu	jaychiu@paulhastings.com
Arthur G. Connolly, III	aconnollyIII@cblh.com, dkt@cblh.com; telwell@cblh.com
Frederick L. Cottrell, III	cottrell@rlf.com
Francis DiGiovanni	fdigiovanni@cblh.com, ddunmeyer@cblh.com; dkt@cblh.com; ljarrell@cblh.com
Thomas M. Dunham	dunhamt@howrey.com
Kevin C. Ecker	kecker@stroock.com
Amy Elizabeth Evans	aevans@crosslaw.com
York M. Faulkner	york.faulkner@finnegan.com
Maxwell A. Fox	maxwellfox@paulhastings.com
Terry D. Garnett	terrygarnett@paulhastings.com
Christopher J. Gaspar	cgaspar@milbank.com

Alexander E. Gasser	agasser@oblon.com
Alan M. Grimaldi	grimaldia@howrey.com
Thomas C. Grimm	tcgefiling@mnat.com
Thomas Lee Halkowski	halkowski@fr.com, sub@fr.com
Angie Hankins	ahankins@stroock.com
Richard L. Horwitz	rhorwitz@potteranderson.com, dmoore@potteranderson.com; nmcmenamin@potteranderson.com; achin@potteranderson.com; mbaker@potteranderson.com; ntarantino@potteranderson.com; kmorris@potteranderson.com; iplitigation@potteranderson.com
Dan C. Hu	hu@tphm.com, gyount@tphm.com; awoods@tphm.com
John T. Johnson	jjohnson@fr.com, lperez@fr.com; autuoro@fr.com
Robert J. Katzenstein	rjk@skfdelaware.com, eys@skfdelaware.com
Nelson M. Kee	keen@howrey.com
Richard D. Kelly	rkelly@oblon.com
Matthew W. King	king@rlf.com
Stephen S. Korniczky	stephenkorniczky@paulhastings.com
Hamilton Loeb	hamiltonloeb@paulhastings.com
Robert L. Maier	Robert.Maier@BakerBotts.com
David J. Margules	dmargules@BMF-law.com, jspeakman@bmf-law.com
David Ellis Moore	dmoore@potteranderson.com, ntarantino@potteranderson.com
Carolyn E. Morris	carolynmorris@paulhastings.com
Arthur I. Neustadt	aneustadt@oblon.com
Elizabeth A. Niemeyer	elizabeth.niemeyer@finnegan.com
Kevin M. O'Brien	boehydis@bakernet.com

Andrew M. Ollis	aollis@oblon.com
Karen L. Pascale	kpascale@ycst.com, corporate@ycst.com; corpcal@ycst.com
Adam Wyatt Poff	apoff@ycst.com, corporate@ycst.com; corpcal@ycst.com
Leslie A. Polizoti	lpolizoti@mnat.com, lpolizoti@mnat.com
Alana A. Prills	alanaprills@paulhastings.com
Steven J Rizzi	steven.rizzi@weil.com
Lawrence Rosenthal	lrosenthal@stroock.com
Avelyn M. Ross	aross@velaw.com
Philip A. Rovner	provner@potteranderson.com, mstackel@potteranderson.com; nmcmenamin@potteranderson.com; iplitigation@potteranderson.com
Diana M. Sangalli	dsangalli@tphm.com
Robert C. Scheinfeld	robert.scheinfeld@bakerbotts.com
Carl E. Schlier	cschlier@oblon.com
Chad Michael Shandler	shandler@rlf.com, pstewart@rlf.com
John W. Shaw	jshaw@ycst. com, corporate@ycst.com; ptorterotot@ycst.com; corpcal@ycst.com
Matthew W. Siegal	msiegal@stroock.com
Neil P. Sirota	neil.sirota@bakerbotts.com
Monte Terrell Squire	msquire@ycst.com
William J. Wade	wade@rlf.com
Peter J. Wied	peterwied@paulhastings.com
Roderick B. Williams	rickwilliams@velaw.com, smendoza@velaw.com

Vincent K. Yip	vincentyip@paulhastings.com
Edward R. Yoches	bob.yoches@finnegan.com
Steven J. Balick	sbalick@ashby-geddes.com
Paul A. Bradley	pab@maronmarvel.com
John G. Day	jday@ashby-geddes.com
Tara D. Elliott	elliott@fr.com
Barry M. Graham	barry.graham@finnegan.com
Darren M. Jiron	darren.jiron@finnegan.com
William J. Marsden, Jr.	marsden@fr.com
Matt Neiderman	mneiderman@duanemorris.com
Timothy J. Vezeau	timothy.vezeau@kmzr.com

I further certify that on August 15, 2006, I caused a copy of the foregoing document to be served by e-mail on the below-listed counsel:

Thomas C. Grimm [tgrimm@mnat.com]
Leslie A. Polizoti [lpolizoti@ mnat.com]
MORRIS, NICHOLS, ARSHT & TUNNELL LLP
1201 North Market Street
Wilmington, DE 19899-1347
Attorneys for Honeywell International Inc. and Honeywell Intellectual Properties Inc.

Steven J. Balick [sbalick@ashby-geddes.com]
John G. Day [jday@ashby-geddes.com]
ASHBY & GEDDES
222 Delaware Avenue
P.O. Box 1150
Wilmington, DE 19899
Attorneys for Honeywell International Inc. and Honeywell Intellectual Properties Inc.

Martin R. Lueck [MRLueck@rkmc.com]
Matthew L. Woods [MLWoods@rkmc.com]
Jacob S. Zimmerman [JSZimmerman@rkmc.com]
Marta M. Chou [MMChou@rkmc.com]
ROBINS, KAPLAN, MILLER & CIRESI LLP
2800 LaSalle Plaza
800 LaSalle Avenue
Minneapolis, MN 55402-2015
Attorneys for Honeywell International Inc. and Honeywell Intellectual Properties Inc.

Alan E. McKenna [AEMckenna@rkmc.com]
Anthony A. Froio [AAFroio@rkmc.com]
Jeremy C. McDiarmid [JCMcDiarmid@rkmc.com]
ROBINS, KAPLAN, MILLER & CIRESI LLP
111 Huntington Avenue, Suite 1300
Boston, MA 02199-7610
Attorneys for Honeywell International Inc. and Honeywell Intellectual Properties Inc.

William J. Wade [wade@rlf.com]
RICHARDS, LAYTON & FINGER
One Rodney Square
P.O. Box 551
Wilmington, DE 19899
Attorneys for Arima Display Corporation, Matsushita Elecrical Industrial Co., and Matsushita Electrical Corporation of America

Richard L. Horwitz [rhorwitz@potteranderson.com]
David E. Moore [dmoore@potteranderson.com]
POTTER ANDERSON & CORROON
6th Floor, Hercules Plaza
1313 N. Market Street
P.O. Box. 951
Wilmington, DE 19801
Attorneys for BOE-Hydis Technology Co., Ltd., Hitachi Displays, Ltd., Koninklijke Philips Electronics N.V., Philips Electronics North America Corp., Samsung SDI America, Inc., and Samsung SDI Co., Ltd., Toppoly Oproelectronics Corp., Wintek Corp., Wintek Electro-Optics Corporation;

Thomas L. Halkowski [halkowski@fr.com]
FISH & RICHARDSON, P.C.
919 N. Market Street, Suite 1100
P.O. Box 1114
Wilmington, DE 19801
Attorneys for Casio Computer Co., Ltd., and Casio, Inc.

Philip A. Rovner [provner@potteranderson.com]
POTTER, ANDERSON & CORROON
6th Floor, Hercules Plaza
1313 N. Market Street
Wilmington, DE 19801
Attorneys for Fuji Photo Film Co. Ltd. And Fuji Photo Film U.S.A. Inc.

William J. Marsden, Jr. [marsden@fr.com]
Fish & Richardson, P.C.
919 N. Market Street, Suite 1100
P.O. Box 1114
Wilmington, DE 19899-1114
Attorneys for International Display Technology and International Display Technology USA, Inc.

John W. Shaw [jshaw@ycst.com]
Monté T. Squire [msquire@ycst.com]
YOUNG CONAWAY STARGATT & TAYLOR LLP
The Brandywine Building
1000 West Street, 17th Floor
P.O. Box 391
Wilmington, DE 19899-0391
Attorneys for Quanta Display Inc., Sony Corporation, Sony Corporation of America, and ST Liquid Crystal Display Corp.

Robert J. Katzenstein [rjk@skfdelaware.com]
Robert K. Beste, III [rkb@skfdelaware.com]
SMITH, KATZENSTEIN & FURLOW
800 Delaware Avenue
P.O. Box 410
Wilmington, DE 19899
Attorneys for Seiko Epson Corporation and Sanyo Epson Imaging Devices Corporation

David J. Margules [dmargules@bmf-law.com]
John M. Seaman [jseaman@bmf-law.com]
BOUCHARD MARGULES & FRIEDLANDER, P.A.
222 Delaware Avenue, Suite 1400
Wilmington, DE 19801
Attorneys for Citizen Watch Co., Ltd., and Citizen Displays Co., Ltd.

YOUNG CONAWAY STARGATT & TAYLOR, LLP

Karen L. Pascale

August 15, 2006

Karen L. Pascale. (#2903) [kpascale@ycst.com]
The Brandywine Building
1000 West Street, 17th Floor
Wilmington, DE 19801
(302) 571-6600
Attorneys for Optrex America, Inc.